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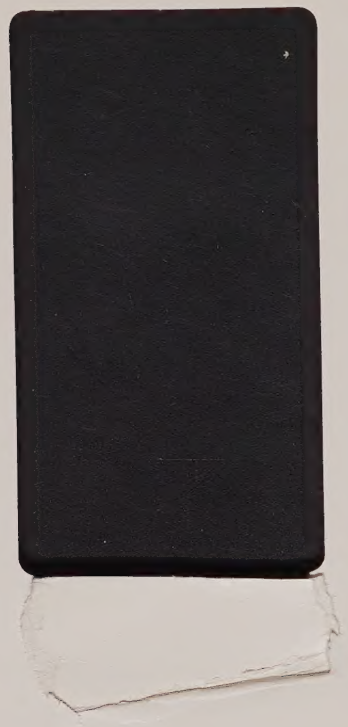
WAVETEK

9045 BALBOA AVENUE, SAN DIEGO, CALIFORNIA



Serial Number
129590

PRELIMINARY
INSTRUCTION MANUAL

MODEL 220

DIALAMATIC
MULTIMETER/CALIBRATOR

WARRANTY

All Wavetek instruments are warranted against defects in material and workmanship for a period of two years after date of manufacture. Wavetek agrees to repair and replace any assembly or component (except batteries) found to be defective under normal use during this period. Transfermatic Switch assemblies, manufactured by Wavetek, are unconditionally warranteed for the life of the instrument. Wavetek's obligation under this warranty is limited solely to repairing any such instrument which in our sole opinion proves to be defective within the scope of the warranty when returned to the factory or to an authorized service center. Transportation to the factory or service center is to be prepaid by purchaser and should not be sent without prior authorization by Wavetek.

This warranty does not apply to any of our products which have been repaired or altered by persons not authorized by us, or not in accordance with instructions furnished by us. If the instrument is defective as a result of misuse, improper repair, or abnormal conditions or operations, repairs will be billed at cost.

Wavetek assumed no responsibility for its product being used in a hazardous or dangerous manner either alone or in conjunction with other equipment. High voltage used in some instruments may be dangerous if misused. Special disclaimers apply to these instruments. Wavetek assumes no liability for secondary charges or consequential damages and, in any event, Wavetek's liability for breach of warranty under any contract or otherwise, shall not exceed the purchase price of the specific instrument shipped and as to which a claim is made.

Any recommendations made by Wavetek for the use of its products are based upon tests believed to be reliable, but Wavetek makes no warranty of the results to be obtained. This warranty is in lieu of all other warranties, express or implied, and no representative or person is authorized to represent or assume for us any liability in connection with the sale of our products other than set forth herein.

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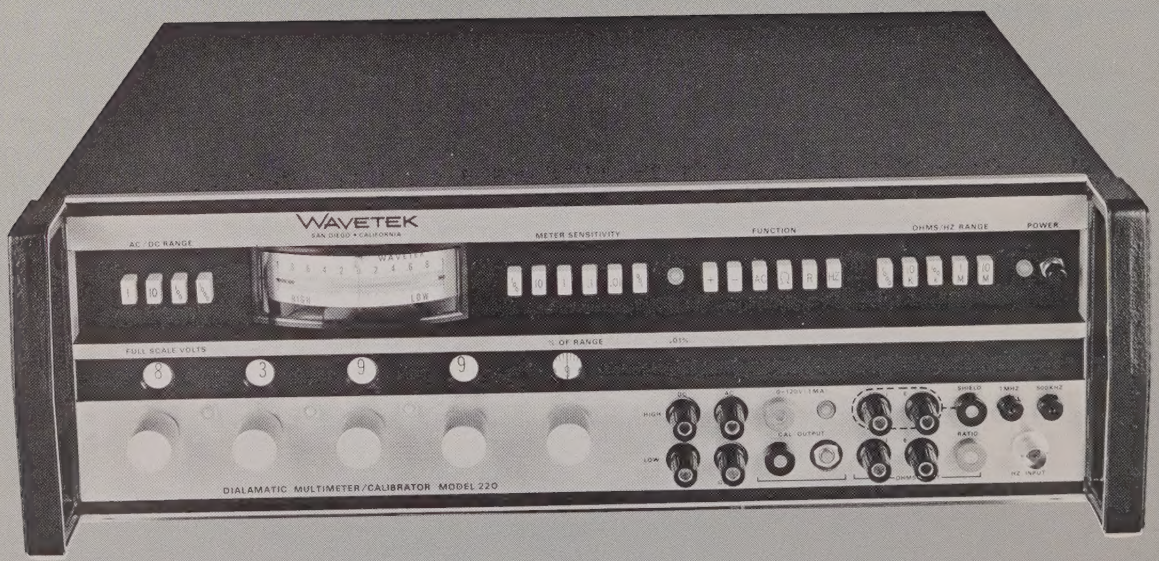

WAVETEK
SAN DIEGO • CALIFORNIA
AC - DC RANGE
METER SENSITIVITY
FUNCTION
OHMS/HZ RANGE
POWER
FULL SCALE VOLTS
% OF RANGE
.01%
CAL OUTPUT
RATIO
SHIELD
1MHZ
100KHZ
HZ INPUT
DIALAMATIC MULTIMETER/CALIBRATOR MODEL 220

SECTION 1
TECHNICAL CHARACTERISTICS

SCOPE OF MANUAL

This preliminary manual provides instructions for operating, testing, and calibrating the Wavetek Model 220 Dialamatic Multimeter/Calibrator. This manual will be replaced by an Instruction Manual that includes complete maintenance data as soon as the information is available.

SCOPE OF EQUIPMENT

The Model 220 Dialamatic Multimeter/Calibrator is a multifunction solid-state instrument that provides precise measuring and calibrating capabilities, including six precision measurement functions and two highly accurate calibration outputs. Operating on the potentiometric principle, the instrument provides laboratory-standard measurements of dc voltage, dc ratio, ac voltage, ohms, ohms ratio, and frequency. The calibrating outputs are 1) dc voltage from 0 to 120 Vdc at 1 milliampere and 2) frequency at 500 kHz and 1 MHz.

Basic instrument accuracies range from 0.005 percent for dc to 0.1 percent for ac. Improved digital/analog readout with six-digit resolution is accomplished by the exclusive *dialamatic* switch and taut-band, edge-reading null meter. The analog deviation display provides an accurate visual indication of the dynamic conditions usually encountered when monitoring or tuning a circuit. A parallel recorder output is available to permit permanent recording.

MODES OF OPERATION

DC Voltmeter

DC voltage can be measured from 0 to 1000 volts in four ranges with a basic accuracy of 0.005 percent. The potentiometric technique provides an input impedance greater than 100,000 megohms for measurements up to 120 volts, thereby eliminating measurement errors due to source impedance. Meter sensitivity in increments of 10, from 100 percent to 0.001 percent, are selectable with a front-panel switch for all ranges except the 1-volt range, which is limited to a maximum sensitivity of 0.01 percent.

AC Voltmeter

Ac voltage can be measured from 0 to 1000 volts in four ranges with a basic accuracy of 0.1 percent. Input impedance is 1 megohm and 40 pF for all ranges. Meter sensitivity to 0.01 percent can be selected. Frequency range of the measured signal can be from 5 Hz to 100 kHz. The ac signal is converted to the average value of a precision-rectified wave and the instrument is calibrated in rms units for a sine wave.

Ohmmeter

Resistance can be measured from 0 to 12 megohms in five ranges with a basic accuracy of 0.005 percent. The potentiometric technique permits the temperature coefficient of a resistor to be determined with 0.2 ppm resolution. Terminals are provided for either two-wire or four-wire measurements and for guard-shield connection.

Hertzmeter

Frequency can be measured from 10 Hz to 12 MHz in five ranges with a basic accuracy of 0.01 percent. The hertzmeter input sensitivity is extremely broad, being from 200 mV to 250 V. Input impedance is 1 megohm, shunted by 40 picofarads, for up to 5 volts peak.

DC Ratiometer

Dc voltage ratios can be measured for reference inputs up to 10.5 Vdc with terminal linearity of 0.001 percent. All dc ranges will track the reference voltage accurately. Use of an external precision voltage divider permits ratio measurements of any reasonable voltage. Input resistance for the reference voltage is 25 kilohms.

Ohms Ratiometer

Resistance ratios can be measured from 0 to 1.2 times reference resistance with an absolute accuracy of 0.005 percent and a 0.002 percent linearity value. Permissible resistance range of the reference resistor is from 2 kilohms to 1 megohm.

DC Calibrator

A continuously variable dc voltage from 0 to 120 volts in two ranges at 0.005 percent accuracy is available at a front-panel connector. Maximum load current is 1 mA. A front-panel indicator illuminates when voltage is present at the connector. An automatic trip circuit disables the output voltage if the current capability is exceeded.

Frequency Calibrator

Fixed-frequency outputs of 500 kHz and 1 MHz are available at two front-panel connectors. Accuracy is 0.001 percent and terminal linearity is better than 0.002 percent. Output frequency can be used in "self-calibrate" operation to check or calibrate the hertzmeter.

Recorder Driver

The output of the potentiometric amplifier that is connected in the null meter circuit is also connected to terminals on the rear panel for connection to a strip-chart recorder. Full-scale null meter deflection results in ±300 mV across these terminals. Output resistance is 10 kilohms with terminals floating above chassis ground.

FUNCTIONAL DESCRIPTION

Dialamatic Bridge

The input to the *dialamatic* bridge (Figure 1-1) is the output of the 10-volt reference supply. The resistor bridge is designed so that critical resistors can be wound from the same spool of wire, resulting in a set of resistors possessing almost perfect temperature tracking. The reference voltage is converted to BCD levels by closure of the *dialamatic* switch contacts. The resultant binary count, 1 through 10, causes the output of operational amplifier A1 to vary proportionally. The "4" in the most-significant-bit (MSB) position is obtained for decimal settings of 8, 9, and 10. The 45-kilohm feedback resistor is shunted in the 1 and

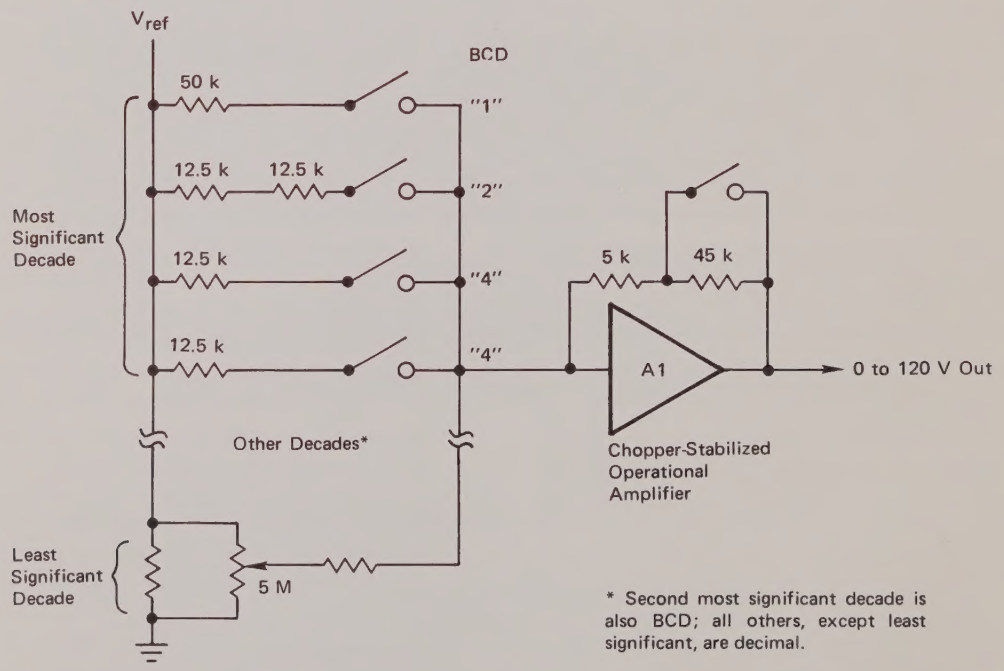


Figure 1-1. *Dialamatic* Bridge/Operational Amplifier

10-volt ranges to limit the A1 output to 12 volts. In other voltage ranges, the resistor is connected in the feedback path and the maximum output is 120 volts.

DC/Calibrate Mode

The basic differential voltmeter circuit utilizes the potentiometric technique to provide highly accurate measurements unaffected by source resistance. This circuit essentially consists of a potentiometric amplifier with a null meter/sensitivity selection circuit in its feedback path (Figure 1-2). The dc input is applied to the input terminal. The common terminal is connected to the *dialamatic* bridge operational amplifier output. When the *dialamatic* switch setting causes operational amplifier A1 to produce an output voltage equal to the input signal, the null amplifer (NA) output is zero and the meter pointer is centered. A recorder output, proportional to meter deflection, provides a permanent recording capability.

Polarity switching (DC+ or DC—) provides the correct polarization of the voltage applied to the null amplifier inverting terminal. In the calibration mode, the potentiometric amplifier circuit is not effective and the output of operational amplifier A1 is connected across the calibration output terminals.

Ohmmeter Mode

Resistance measurements are made by comparing the BCD potential produced by the *dialamatic* bridge/operational amplifier circuit with the potential resulting from the

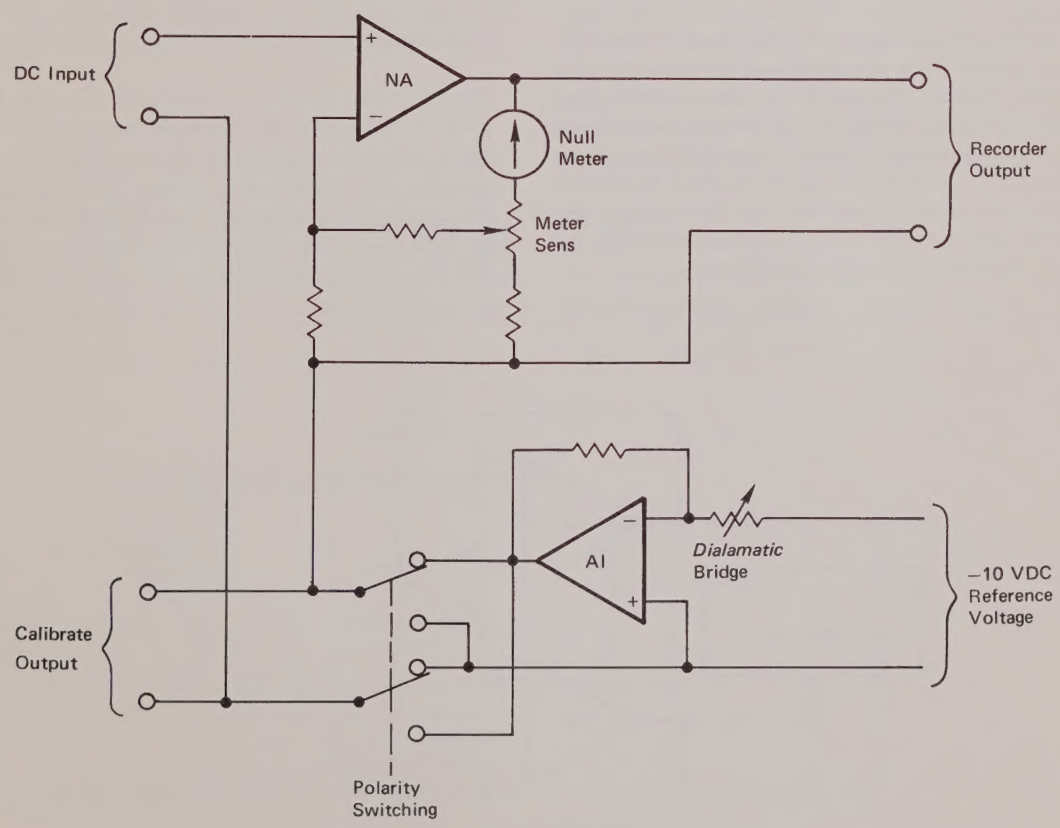


Figure 1-2. DC/Calibrate Mode

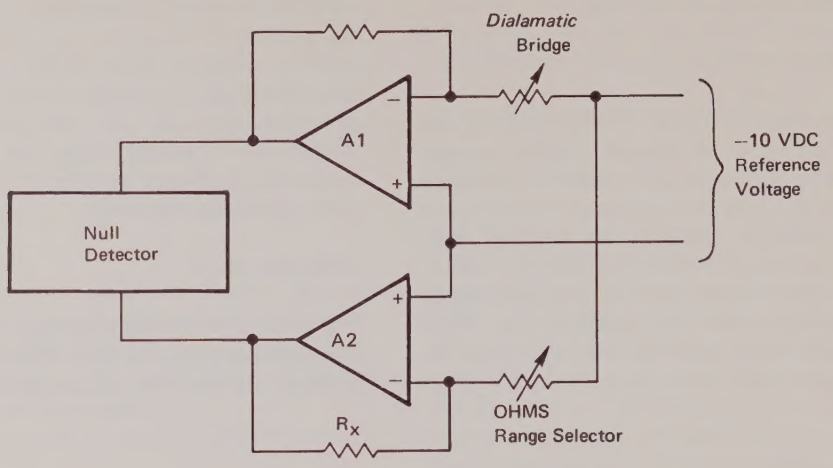


Figure 1-3. Ohms Mode

unknown resistor/operational amplifier circuit (Figure 1-3). Unknown resistor R_X is connected in the feedback path of operational amplifier A2, while the selected ohms-range resistance is connected between the reference voltage and the A2 input. The output of the A2 operational amplifier is applied to the input of the null amplifier. When the A1 and A2 outputs are equal in amplitude, the meter pointer will be centered, and the value of R_X can be determined by the *dialamatic* readout and the ohms-range setting.

Ohms-Ratio Mode

The functional aspects of this mode are very similar to those of the ohms mode. The major functional difference is that a standard resistance (2 kΩ to 1 MΩ at 5 mA max) replaces the ohms-range resistor (Figure 1-4) Two measurement techniques are used. With R_X approximately equal to R_{std}, the *dialamatic* switches are set to display 1000000. The pointer deflection then indicates deviation as

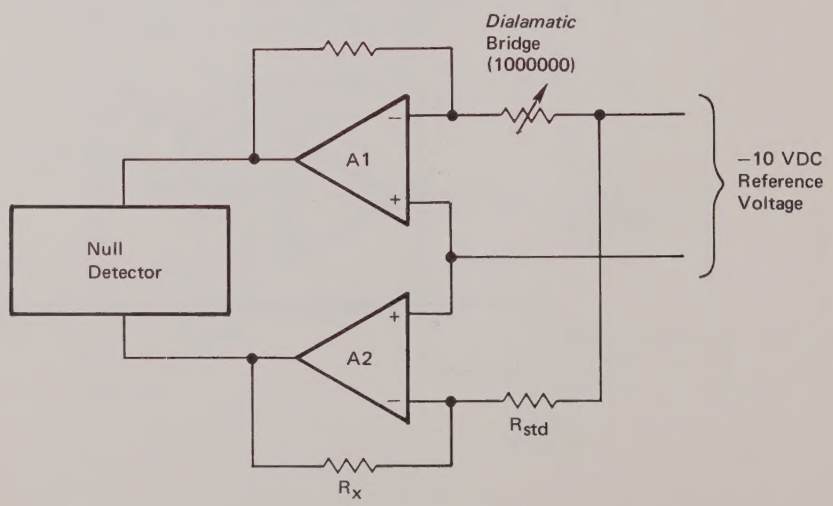


Figure 1-4. Ohms-Ratio Mode

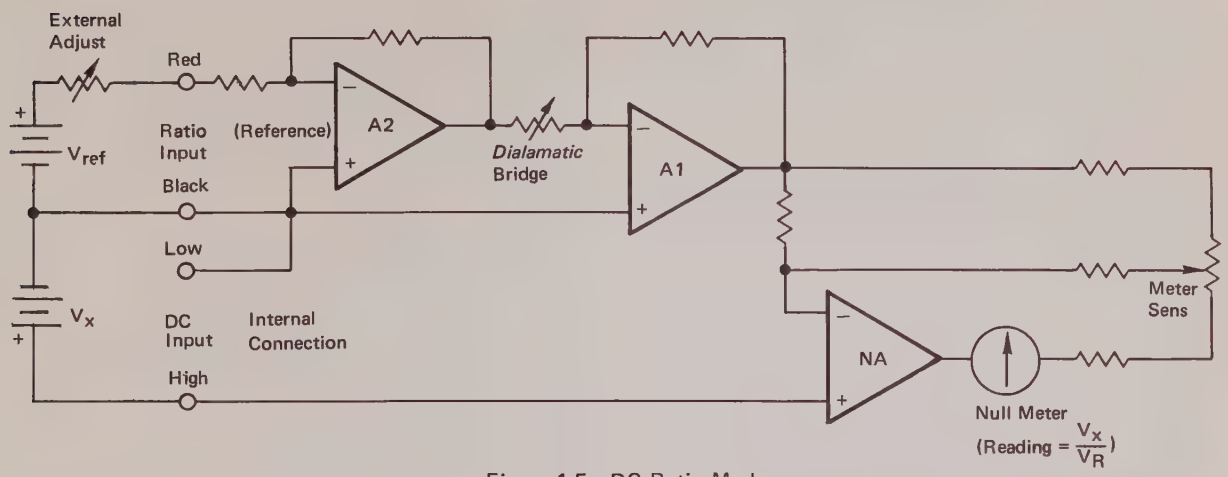


Figure 1-5. DC Ratio Mode

a percentage of the reference resistor value. The other measurement technique is the conventional method whereby the *dialamatic* reading at null indicates the ratio of the unknown resistance to the reference resistance.

DC Ratio Mode

The reference mode is used primarily to measure the ratio of positive dc voltages (Figure 1-5). Meter deflections are based on a 10-volt dc reference, and this voltage should be used whenever possible. Recommended reference voltages are from 0 to 10.5 volts. All ranges are referenced to this reference voltage for positive ratios. Negative ratios are limited to the 1-volt and 10-volt ranges. Higher reference voltages, such as 100 volts can be reduced to the required level with an external 10:1 divider. The reference input resistance is 25 kilohms. The ratio input can also be used as a dc amplifier by selecting either the 1, 10, or 100 volt dc ranges (1 or 10 volts for negative input) and using the calibrate output. Ratios from 0 to 120 percent of the reference can be read on the *dialamatic* switches.

AC Mode

Ac conversion is accomplished by an operational amplifier/average rectifier circuit (Figure 1-6). The

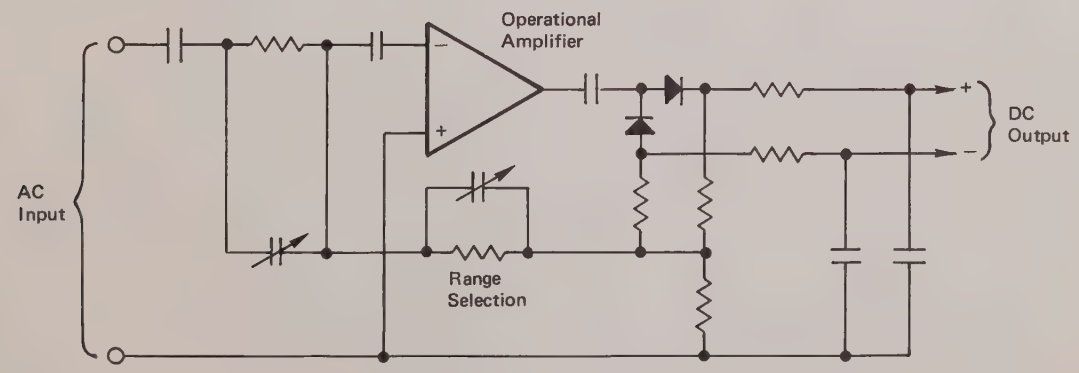


Figure 1-6. AC Converter

high-gain operational amplifier ensures stability and linearity. The rectifier converts the input waveform to the average dc value. The following null detector circuit is designed to provide a readout that is equal to the rms value of a sine wave.

Frequency Mode

Conversion of the input frequency into a proportional dc voltage for the null detector is accomplished by generating a precise 400-μsec pulse whose repetition rate is a function of the input frequency (Figure 1-7). The input frequency is divided down to a common working value of 1-kc full scale for all frequency ranges and applied to the trigger input of a gating flip-flop. The gate enables the one-shot counter to produce a crystal-controlled 400-μsec pulse. The counter output drives a precision analog switching circuit whose output, when measured in the dc ratio mode, results in a average-frequency reading with better than 0.01 percent accuracy.

DC VOLTMETER SPECIFICATIONS

Input 000.0$_{00}$ mV to 1199.9$_{99}$ V in four ranges: 1 V, 10 V, 100 V, and 1000 V.
Polarity Front panel selected plus or minus.
Accuracy Basic accuracy 0.005% of reading depending on range as shown below (25°C ±5°C).

Range (volts)	Accuracy	Minimum Input Resistance (Ω)
1	±0.005% of reading +0.001% of range +10 μV	10^{10}
10	±0.005% of reading +0.001% of range	10^{11}
100	±0.005% of reading +0.001% of range	10^{11}
1000	±0.01% of reading +0.001% of range	10^{7}

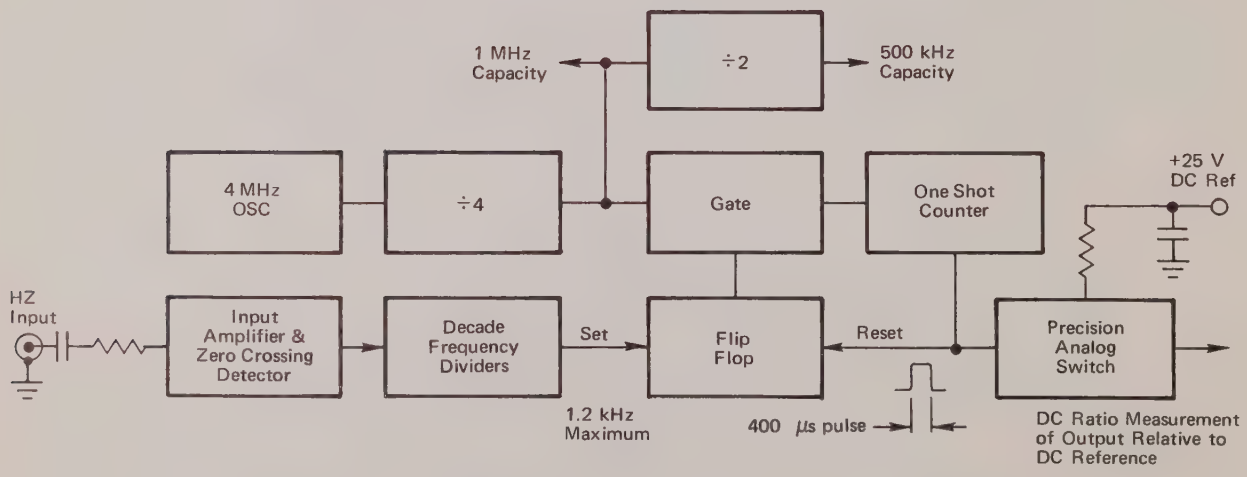


Figure 1-7. Frequency Converter

Temperature Coefficient 10°C to 40°C.
1-V, 10-V and 100-V range; less than 5 ppm/°C.
1000-V range; less than 10 ppm/°C.
Maximum Common Mode Voltage
500 Vdc or ac peak with 1 kΩ unbalance in either side of input and up to 70% relative humidity.

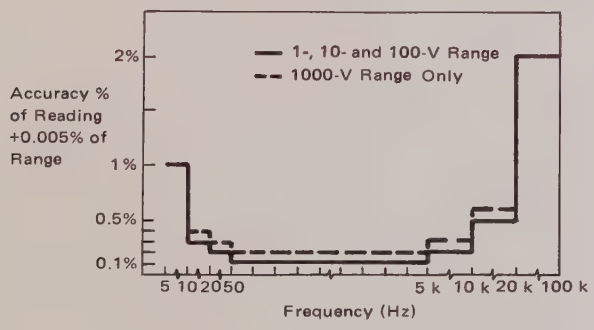
Effective Common Mode Rejection, db

Range	DC	50 Hz	400 Hz
1 V	160	140	130
10 V	160	120	110
100 V	140	110	90
1 kV	120	90	70

Effective Normal Mode Rejection
60 db minimum at 60 Hz.

AC VOLTMETER SPECIFICATIONS

Input Voltage 0.001$_{00}$ V to 1199.9$_{99}$ V rms in four ranges: 1 V, 10 V, 100 V, and 1000 V.
Input Frequency 5 Hz to 100 kHz.
Accuracy Basic accuracy ±0.1% of reading +0.005% of range depending on frequency and range as shown below.



Minimum Input Voltage (ac)

	1-, 10-, and 100-V Range	1000-V Range
5 Hz–5 kHz	1 mV	1 V
5 kHz–10 kHz	3 mV	3 V
>10 kHz	100 mV	10 V

Input Impedance 1 MΩ, 40 pF.
Calibration Average value of precision-rectified wave calibrated to read rms value of a sine wave.

FREQUENCY MEASUREMENT SPECIFICATIONS

Input 010.0$_{00}$ Hz to 11.999$_{99}$ MHz in five ranges: 1 kHz, 10 kHz, 100 kHz, 1000 kHz, and 10 MHz.
Accuracy ±0.01% of reading +0.001% of range (all ranges).
Input Sensitivity 200 mV to 250 V rms, no sensitivity control required.
Input Impedance 1 MΩ and 40 pF to 5 V peak, 100 kΩ and 100 pF above 5 V.
Response to Step Input To ±0.01% of range in 3 sec.

DC RATIO SPECIFICATIONS

Input Maximum ±10.5 Vdc (higher reference voltages can be used with an external divider). All dc ranges are ratioed to external reference voltage.
Ratio Terminal Linearity ±0.001%.

OHMMETER SPECIFICATIONS

Input 000.0$_{00}$ Ω to 11.999$_{99}$ MΩ in five ranges: 1 kΩ, 10 kΩ, 100 kΩ, 1000 kΩ, and 10 MΩ.
Accuracy ±0.005% of reading +0.001% of range, depending on range as shown below.

Range	Accuracy	Test Current	Max Voltage Across Resistor
1 kΩ	±0.01% of reading +0.002% of range.	1 mA	1.2 V
10 kΩ	±0.005% of reading +0.001% of range.	1 mA	12 V
100 kΩ	±0.005% of reading +0.001% of range.	100 μA	12 V
1000 kΩ	±0.01% of reading +0.001% of range.	10 μA	12 V
10 MΩ	±0.02% of reading +0.001% of range.	1 μA	12 V

Ohms Connections
Four binding posts for four-wire measurements with shorting bars provided for two-wire measurements. Terminal provided for guard-shield connection, and ratio reference.

OHMS RATIO (DEVIATION) SPECIFICATIONS

Standard Resistor Range 2 kΩ to 1 MΩ.
Unknown Resistor Range 0 to 1.2 times standard.
Absolute Ratio Accuracy ±0.005%.
Linearity 0.002%.

DC CALIBRATOR SPECIFICATIONS

Range 0.000$_{00}$ V to 119.9$_{99}$ V in two ranges, continuously variable.
Accuracy ±0.005% of reading +0.001% of range.
Current 1 mA maximum.
Current Indicator Front-panel light indicating calibrated voltage present at output. Automatic trip circuit if current

capability is exceeded.

FREQUENCY CALIBRATOR SPECIFICATIONS

Output Crystal-controlled test outputs at 500 kHz and 1 MHz for single-point calibration.
Accuracy ±0.002%.

GENERAL

Digital Readout Six-digit potentiometric control with associated dial indicators; four switches and one potentiometer in the least-significant decade having two-digit resolution.
Analog Readout Edge-reading, taut-band null indicator with center null.
Meter Sensitivity Front-panel pushbutton selectable percentage of range. Values of ±0.001, ±0.01, ±0.1, ±1, ±10 and ±100% of range.

Note: The 0.001% meter sensitivity is not selectable on the following function and range combinations: dc volts 1 V, ohms 1 kΩ; ac volts, all ranges. If one of these combinations is selected, the meter automatically goes to the 0.01% sensitivity and an 0.01% indicator lights on the front panel.

Transistorized Direct Meter The null meter may be used as a direct-reading volt, ohm, or frequency meter when in 100% sensitivity. Meter accuracy 3% of full scale.
Null Meter Resolution 0.2 ppm of range when in 0.001% sensitivity. Value is equal to one minor division on mirror scale.
Transfermatic Switch Resolution 0.5 ppm of range. Value equal to one-half minor dial division.
Recorder Output ±300 mV for full-scale meter deflection. Source impedance 10 k.
Reference Voltage Stability 0.0005% per hour at constant temperature.
Environmental All specifications apply at 25°C ±5°C after one-half hour warmup.
Dimensions 17 in. wide, 5¼ in. high, 16 in. deep.
Weight Approximately 25 lb, 35 lb shipping.
Power Requirements 105–125 V or 200–250 V, 50 to 400 Hz. Less than 50 W.

SECTION 2
OPERATION INSTRUCTIONS

INSTALLATION

Conversion for 230-Volt Line Power

The Model 220 is shipped from the factory with the power transformer connected for 115-volt line power, unless otherwise specified. To convert the transformer primary for 230-volt operation, insert a small-bladed screwdriver in the slotted switch on the rear panel and move the toggle to the 230 position.

INSPECTION

The following procedures should be performed to assure the user that the instrument has arrived at its destination in proper operating condition. Complete field calibration and checkout instructions are given in Section 3 for determining if the instrument is within electrical specifications.

Visual Inspection

Visually inspect the external case for damage to knobs, dials, indicator glass, surface areas, etc. If damage is discovered, file a claim with the carrier who transported the instrument.

Operating Inspection

NOTE

Refer to *Installation* instructions for 115-volt or 230-volt line power information.

The procedural steps in Table 2-1 provide a quick checkout of instrument operation. If electrical deficiencies exist, refer to the *Warranty* in the front of this manual. Table 2-2 and Figure 2-1 provide descriptive data for the operating controls. The following test equipment, or equivalent, is recommended for performing the electrical inspection.

OPERATING CONTROLS

NOTE

After the initial step of depressing the POWER pushbutton, *a 10-minute warmup* is required for the Model 220 parameters to be within specifications.

Name	Manufacturer	Model
0 to 10 Vdc source	any	–
Ac voltage source	115 V line	–
Frequency source	60 Hz line	–
1 kΩ, 10 kΩ, 100 kΩ, 1 M resistors 10%, ½ W	any	–

Figure 2-1 illustrates the Model 220 controls, indicators, and connectors. Table 2-2 gives a condensed functional description of each item illustrated in Figure 2-1.

OPERATION

Preliminary Procedures

The following procedural steps are common to all Model 220 operations and should be performed first.

1. Check that 115-230 volt power switch on rear panel is in the correct position.
2. Depress POWER pushbutton and check that lamp lights.
3. Allow *10-minute warmup* for Model 220 to stabilize before making critical measurements.

Operating for Analog Readouts

The Model 220 can be used as a direct-reading meter for any of its measurement functions by proceding as follows:

1. Depress the 100% OF RANGE METER SENSITIVITY pushbutton.
2. Select desired function and range and make connections for the parameter to be measured as described in the specific *measurement* paragraphs.
3. Read the parameter value directly from the meter deflection. The *dialamatic* switches are disconnected at 100% sensitivity and, therefore, have no effect on the meter. Full-scale meter deflection will correspond to selected range value.

Step	Type of Check	External Input	MODEL 220 Control Settings							
			Dials					AC/DC RANGE	METER SENSITIVITY	FUNCTI
			A	B	C	D	E			
1	Preliminary	–	–	–	–	–	–	–	–	–
2	10 Vdc zero	–	0	0	0	0	00	10	.001	+
3	100 Vdc zero	–	0	0	0	0	00	100	.001	+
4	1000 Vdc zero	–	0	0	0	0	00	1000	.001	+
5	1 Vdc zero	–	0	0	0	0	00	1	.01	+
6	.01%/10 Vdc sens.	–	0	0	0	1	00	10	.01	+
7	.1%/10 Vdc sens.	–	0	0	1	0	00	10	.1	+
8	1%/10 Vdc sens.	–	0	1	0	0	00	10	1	+
9	10%/10 Vdc sens.	–	1	0	0	0	00	10	10	+
10	.01%/100 Vdc sens.	–	0	0	0	1	00	100	.01	+
11	.1%/100 Vdc sens.	–	0	0	1	0	00	100	.1	+
12	1%/100 Vdc sens.	–	0	1	0	0	00	100	1	+
13	10%/100 Vdc sens.	–	1	0	0	0	00	100	10	+
14	Cal/VM/Sw "A"	–	0	0	0	0	00	10 ~	100	+
11	Switch "B"	–	0	0	0	0	00	10	10	+
12	Dc △VM	0 to 12 Vdc	0	0	0	0	00	10	10	+
13	Ac △VM	0 to 10 Vac	0	0	0	0	00	10	10	AC

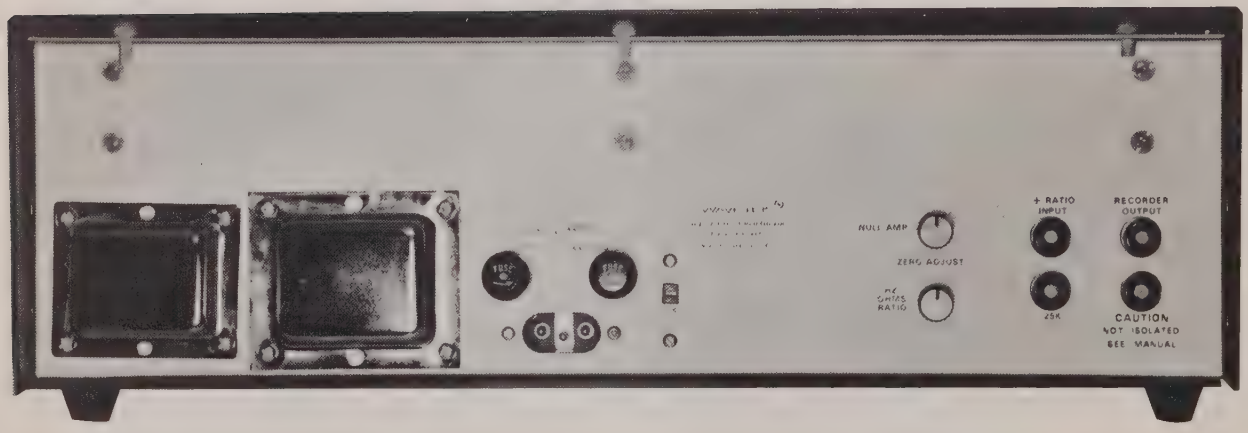
	OHMS/HZ RANGE	Operating Procedures	Required Result	Remarks
	–	Depress POWER switch.	Lamp lights.	Meter mechanical zero should be aligned before turning power on.
	–	Short dc input with copper alloy test clip.	$<$40% FS deflection.	Do not use iron-alloy clip because of thermal emf.
	–	Short dc input with copper alloy test clip.	$<$40% FS deflection.	
	–	Short dc input with copper alloy test clip.	$<$40% FS deflection.	
	–	Short dc input with copper alloy test clip.	$<$10% FS deflection.	
	–	Short dc input.	FS ±5%	Add zero shift for correct deflection.
	–	Short dc input.	FS ±5%	
	–	Short dc input.	FS ±5%	
	–	Short dc input.	FS ±5%	
	–	Short dc input.	FS ±5%	
	–	Short dc input.	FS ±5T	
	–	Short dc input.	FS ±5%	
	–	Short dc input.	FS ±5%	
	–	a. Connect jumper red CAL OUT terminal to DC IN HIGH terminal and press red calibrate button.	CAL lamp lights.	
		b. Turn dial "A" from 0 thru 10.	Meter deflects to left, increasing in proportion to dial number with "10" indicating full scale ±5%.	Checks direct voltmeter operation and all bits of highest decade switch.
	–	Short dc input and turn dial "B" from 0 thru 9	Meter deflects to left in 10% increments.	
	–	Operate dials "A", "B", & "C" to obtain null; select .1% sens. and operate dials "D" and "E" for null.	Digital readout agrees with dc voltage input level.	Instrument will resolve voltage to 1 ppm with .01% and .001% sens.
		Operate dials "A", "B", & "C" to obtain null; select .1% sens. and operate dials "D" and "E" for null.	Digital readout agrees with ac voltage input level.	Sensitivities greater than .1% are impractical due to instability of most ac voltage sources.

Table 2-1. OPER

Ste	Type of Check	External Input	MODEL 220 Control Settings							
			Dials					AC/DC RANGE	METER SENSITIVITY	FU
			A	B	C	D	E			
14	Ohms zero	—	0	0	0	0	00	—	.01	
15	1 kΩ calibration	Standard resistor at 400Ω to 1 kΩ	Set to value of standard resistor.					—	.01	
16	10 kΩ calibration	Standard resistor at 4 kΩ to 10 kΩ	Set to value of standard resistor.					—	.01	
17	100 kΩ calibration	Standard resistor at 40 kΩ to 100 kΩ	Set to value of standard resistor.					—	.01	
18	1 MΩ calibration	Standard resistor 400 kΩ to 1 MΩ	Set to value of standard resistor.					—	.01	
19	10 MΩ calibration	Standard resistor at 4 MΩ to 10 MΩ	Set to value of standard resistor.					—	.01	
20	Ohms ratio	Two standard resistors at 2 kΩ to 1 MΩ	10	0	0	0	00	—	.01	
21	Frequency accuracy	—	10	0	0	0	00	—	.01	
22	Frequency linearity	—	5	0	0	0	00	—	.01	

NCTION	OHMS/HZ RANGE	Operating Procedures	Required Results	Remarks
Ω	1000	a. Short ohms input adjust rear-panel ohms zero. b. Operate .001% sens. and check zero on 10k, 100k, 1M, and 10M ranges.	Meter nulls. ± 40% FS	Ohms zero adjust normally required only on 1000 Ω range.
Ω	1000	Observe meter.	Meter nulls within meter tolerance plus resistor tolerance.	a. Use 4-wire connections of copper alloy unless very short leads are used. b. For best accuracy, check ohms zero on 1000 Ω range. c. For near FS values and .01% sens., each major dial division represents .001%.
Ω	10 kΩ	Observe meter.	Meter nulls within meter tolerance plus resistor tolerance.	If short resistor leads are used, 2-wire connection is adequate on this range.
Ω	100 kΩ	Observe meter.	Meter nulls within meter tolerance plus resistor tolerance.	
Ω	1 MΩ	Observe meter.	Meter nulls within meter tolerance plus resistor tolerance.	For .01% accuracy, insulation resistance must be not less than 20,000 MΩ. Take care to prevent shorts between SHIELD and OHMS low terminals.
Ω	10 MΩ	Observe meter.	Meter nulls within meter tolerance plus resistor tolerance.	Same as for 1 MΩ calibration check.
M	None	Connect one standard resistor between the OHMS INPUT upper terminal and the RATIO terminal. Connect the second standard resistor (same ohmic value) between the OHMS INPUT terminals.	Meter nulls within meter tolerance plus tolerances of both resistors.	Ignore decimal lamps; the dial setting indicates 100% in this case.
HZ	1M	Connect a jumper from the 1 MHz output to center pin of BNC connector.	Meter nulls within 50% FS deflection.	50% FS deflection equals 0.005% accuracy in this case. Common of BNC connected to chassis ground.
HZ	1M	Connect a jumper from the 500 kHz output to center pin of BNC connector.	Meter nulls within 25% FS deflection.	Do not connect BNC common to ac power line.

Front



Back

Figure 2-1. Model 220 Operating Controls

Table 2-2. CONDENSED OPERATING DATA

Name	Description
Controls	
POWER Pushbutton	Connects line power to unit.
CAL OUTPUT Button	Connects dc calibrate voltage to output terminals when pressed, if +, −, or R FUNCTION pushbutton is depressed, and no overload exists.
FUNCTION Pushbuttons	
+	Connects circuitry for measuring positive dc voltage.
−	Connects circuitry for measuring negative dc voltage.
AC	Connects circuitry for measuring ac voltage.
Ω	Connects circuitry for measuring resistance.
R	Connects circuitry for measuring dc voltage ratios.
HZ	Connects circuitry for measuring frequency.
OHMS/HZ RANGE Pushbuttons	
1000	Sets top of scale for 1000 Ω or 1000 Hz.
10K	Sets top of scale for 10 kΩ or 10 kHz.
100K	Sets top of scale for 100 kΩ or 100 kHz.
1M	Sets top of scale for 1000 kΩ or 1000 MHz.
10M	Sets top of scale for 10 MΩ or 10 MHz.
AC/DC RANGE Pushbuttons	
1	Sets top of scale for 1 volt.
10	Sets top of scale for 10 volts.
100	Sets top of scale for 100 volts.
1000	Sets top of scale for 1,000 volts.
METER SENSITIVITY Pushbuttons	
100	Sets meter sensitivity at 100% of full scale (direct reading).
10	Sets meter sensitivity at 10% of full scale.
1	Sets meter sensitivity at 1% of full scale.
.1	Sets meter sensitivity at 0.1% of full scale.
.01	Sets meter sensitivity at 0.01% of full scale.
.001	Sets meter sensitivity at 0.001% of full scale.
Dialamatic Knobs	Connects various bridge-resistance combinations into input of operational amplifier for nulling meter.
NULL AMP ZERO	Adjusts null amplifer zero on 1 Vdc range.
OHMS ZERO ADJUST	Adjusts ohms zero on 1000 M range.
115-230 Switch	Connects power transformer for 115 or 230 volt line operation.
Indicators	
Null Meter	Operates in conjunction with *dialamatic* switching to provide digital readout, or alone for direct-reading (100% sensitivity) analog readout.
Dialamatic Decimal Lamps	Indicates position of decimal point when illuminated. First lamp (left) lights for decade 10, second for decade 100, third for decade 1000 and 1.
POWER Lamp	Lights when line power is connected to rectifier circuitry.
CAL OUTPUT Lamp	Lights when calibrate voltage is present on output terminals.
.01% Lamp	Lights if 0.001% meter sensitivity is selected for 1 Vdc, 1000 Ω, or any ac range.
Connectors	
1 MHZ Terminal	1 MHz frequency-calibrate signal present between this terminal and BNC common terminal.
500 KHZ Terminal	500 kHz frequency-calibrate signal present between this terminal and BNC common terminal.
CAL OUTPUT Terminals	Calibrate output voltage, as selected by dialamatic dials, present across these two terminals.
RECORDER OUTPUT Terminals	Variable dc voltage (±300 mA full scale) present at these terminals on rear panel.
OHMS INPUT Terminals	2-wire or 4-wire input terminals for resistance measurements, shorting bars removed for 4-wire.
AC Input Terminals	2-wire, plus GUARD, terminals for ac measurements. AC common may also be used as a dc guard terminal.
DC Input Terminals	2-wire, plus GUARD, terminals for either positive or negative dc measurements.
HZ INPUT Terminals	BNC connector for frequency measurements. (Common is connected to chassis.)

Operating for Digital Readout

The specific *measurement* paragraph instructions will provide digital readout for all meter sensitivities except 100%. In the 100% sensitivity selection, the meter deflection/range setting indicates the measured value. In all other sensitivities, the meter is nulled with the *dialamatic* switching and the digital display indicates the measured value when meter is nulled.

1. Select function and range for parameter to be measured as described in the specific *measurement* paragraph.
2. Make desired connections.
3. Depress the 10% OF RANGE METER SENSITIVITY pushbutton.
4. Null meter with *dialamatic* knob, turning knob in direction you wish meter pointer to move.

NOTE

The *dialamatic* switching automatically transfers decades—only one knob need be turned.

5. Repeat Step 3, increasing meter sensitivity until desired accuracy is obtained.
6. Read measured value from digital display.

NOTE

1. The *dialamatic* switching includes a 20% overrange capability; i.e., if the 1000 AC/DC RANGE is selected, full-scale deflection is 1000 volts. However, the most-significant-digit (MSD) dial is numbered from 0 through 11. Therefore, a setting of 1199.999 can be obtained. The least-significant-digit dial, which is continuously variable, can be read to two digits—hence the last two 9's in the preceding numerical example are read from this dial.

2. The 0.001% of range meter sensitivity is not effective in the 1-volt dc range, the 1-k ohms range, or any ac range. If this sensitivity is selected for these ranges, the 0.01% lamp will light to indicate the *actual* meter sensitivity.

Making DC Voltage Measurements

1. Select proper polarity by depressing + or – FUNCTION pushbutton.
2. Depress the 10% OF RANGE METER SENSITIVITY pushbutton.
3. Depress the correct AC/DC RANGE FULL SCALE VOLTS pushbutton.
4. Connect voltage source to DC HIGH and LOW terminals. (Usually the GUARD terminal should be connected to the dc common.)

NOTE

If GUARD terminal is used, don't forget to remove shorting bar between DC LOW and GUARD terminals.

5. Null meter with *dialamatic* switching, remembering to turn knob in the direction that you want the meter pointer to move.
6. Repeat Step 5, increasing meter sensitivity until the desired accuracy is obtained. After the final nulling, read the measured value from the digital dials. Determine position of decimal point by observing which lamp is lit.

Making DC Ratio Measurements

1. Depress the R FUNCTION pushbutton.
2. Depress the AC/DC RANGE pushbutton.
3. Depress the 10% OF RANGE pushbutton.
4. Connect the 1 V to +20.5 Vdc reference voltage (V_{ref}) to the RATIO INPUT terminals with a high-quality 20Ω potentiometer in series with the red terminal. See Figure 2-2.
5. Connect the unknown dc voltage (V_X) to the DC HIGH and LOW terminals.

NOTE

All dc ranges usable for positive ratios. Maximum negative ratio range is 10 volts, where V_{ref} is between –1 V and –10.5 V, and V_X is between 0 V and –12 V.

6. Now the meter must be nulled for the test leads being used, so set dials for 1000000 and temporarily connect the high test lead of the V_X supply to the high side of the V_{ref} supply (Figure 2-2).
7. Null the meter with the 20Ω potentiometer.
8. After nulling the meter, reconnect the V_X high test lead to the V_{ref} supply.
9. Null the meter with the *dialamatic* switching to the desired meter sensitivity. The digital readout will be the proportional value of V_X to V_{ref}. Ignore the decimal lamp. The decimal point will be the second lamp from the left when the proportion is expressed as a percentage; i.e., if V_X is 1.2 V_{ref} the MSD will be 11 and the other dial digits will be 9's for a total of 119.9999%.

Making AC Measurements

1. Depress the AC FUNCTION pushbutton.
2. Depress the correct AC/DC RANGE pushbutton.
3. Depress the 10% OF RANGE METER SENSITIVITY pushbutton.
4. Connect the ac voltage between the AC and GUARD terminals with the shorting bar in place.
5. Null the meter with the *dialamatic* switching to the desired meter sensitivity.
6. Read the measured value from the *dialamatic* digits, determining decimal point location by lamp illumination. (The 1-volt range is read as 1000 mV.)

Making Resistance Measurements

1. Depress the Ω FUNCTION pushbutton.

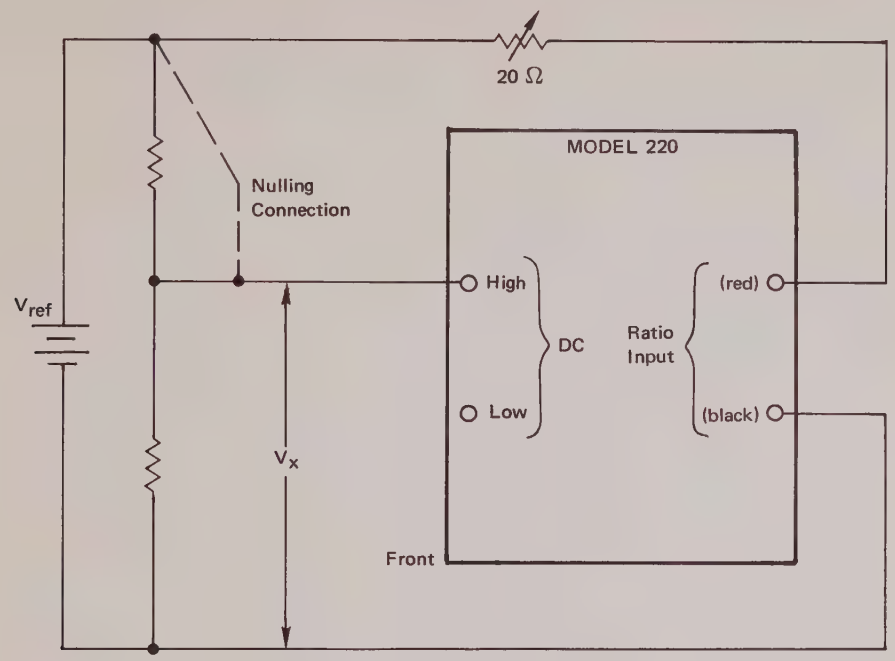


Figure 2-2. DC Ratio Connections

2. Depress the correct OHMS/HZ RANGE pushbutton.
3. Depress the 0.001% OF RANGE METER SENSITIVITY pushbutton.
4. Short the test leads and connect to the OHMS INPUT terminals. Null the meter with the OHMS ZERO ADJUST potentiometer on the rear panel.
5. Now connect the unknown resistance to the test leads and reduce meter sensitivity as required.

NOTE

If 4-wire measurements are to be made, first remove the two shorting bars. Then connect the voltage leads to the **E** terminals and the current leads to the **I** terminals.

6. Null the meter with the *dialamatic* switching to the desired meter sensitivity. The digital readout will be the measured value.

Making Resistance Ratio Measurements

1. Depress the Ω FUNCTION pushbutton.
2. Release any OHMS/HZ RANGE pushbutton that is depressed.
3. Connect a 2 kΩ to 1 MΩ standard resistor (R_{std}) between the OHMS INPUT E (red) terminal and the RATIO terminal. (Shorting bar must be in place.) See Figure 2.3.
4. Connect a 0 to 1.2 R_{std} unknown resistor (R_X) between the two OHMS INPUT I terminals (Figure 2-3). Load current of R_{std} must not exceed 5 mA.
5. Null the meter with the *dialamatic* switching to the desired meter sensitivity. The digital readout will be the proportional value of R_X to R_{std}. Ignore the decimal lamp. The decimal point will be the second lamp from the left when the proportion is expressed as a percentage; i.e., if R_X is 0.8 R_{std}, the MSD will be 8 and the other dial digits will be 0's for a total of 80.0000%.

Making Frequency Measurements

1. Depress the HZ FUNCTION pushbutton.
2. Depress the correct OHMS/HZ RANGE pushbutton.
3. Depress the 10% OF RANGE METER SENSITIVITY pushbutton.
4. Connect the frequency signal to the HZ INPUT BNC connector.
5. Null the meter with the *dialamatic* switching to the

desired meter sensitivity. The digital readout is the measured value.

Recording Small Changes

Where a record of small parameter changes over a long time period is required, such as voltage, frequency, or resistance drift, proceed as follows:

1. Make connections and null meter as previously described for the parameter under measurement.
2. Connect a strip-chart recorder to the RECORDER OUTPUT terminals on the rear panel.
3. Check the strip-chart at desired intervals. Stylus will ink deviations from value of digital readout.

Calibrating with DC Voltage

1. Depress + or — FUNCTION pushbutton.
2. Depress desired AC/DC RANGE pushbutton.
3. Set exact voltage desired on *dialamatic* dials.
4. Connect load to CAL OUTPUT terminals. Load current should not exceed 1 mA.
5. Momentarily press CAL reset button.

NOTE

If maximum load current of 1 mA is exceeded, an internal current-trip relay will disconnect the dc voltage from the CAL OUTPUT terminals. After adjusting load, press CAL reset button to reconnect voltage to output terminals.

Calibrating with Fixed Frequency

Either 500 kHz or 1 MHz can be selected by connecting to front-panel terminal so designated.

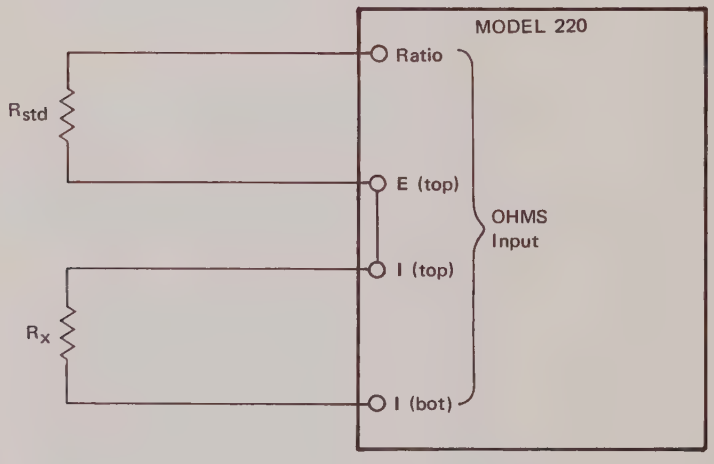


Figure 2-3. Resistance Ratio Connections

SECTION 3
CALIBRATION

INTRODUCTION

This section provides instructions for calibrating the Model 220. Instructions are concise and directed to the experienced electronics technician or field engineer. Wavetek maintains a factory-repair department for those customers not possessing the necessary personnel or test equipment required to calibrate the instrument. If the instrument is returned to the factory for repair, a detailed description of the specific problem should be attached to facilitate the turnaround time.

NOTE

The Model 220 must stablize for not less than 10 minutes after power turn-on and before calibration.

RECOMMENDED TEST EQUIPMENT

The following tabulation lists recommended test equipment. Any test equipment with equal accuracies may be substituted for those listed.

Description	Manufacturer	Model
Ac source, 100 Hz to 10 kHz, 1 V to 1000 V, < 0.1% distortion	Optimation, Inc.	–
Thermal Transfer Voltmeter	Holt	6A
Dc source, 1 V to 1000 V, 0.001% accuracy	Cohu	355

CALIBRATION PROCEDURES

The following subparagraphs provide complete sequential calibration procedures for the Model 220. These same procedures can be used for a quick checkout of instrument electrical operation by performing all steps, except the actual adjustment technique. After familiarization with the complete procedures given here, calibration can be performed quickly and easily with only the calibration plate under the top cover as a guide.

Zero Check and Adjustment

1. Set Model 220 controls as follows:
   a. FUNCTION for +.
   b. AC/DC RANGE for 10.
   c. METER SENSITIVITY for .001%.
2. Short DC HIGH and LOW terminals. If meter deflection is more than 30 percent of full scale, adjust control "U" (marked on calibration plate) to null meter.
3. Set AC/DC RANGE for 1 and adjust NULL AMP ZERO ADJUST on rear panel to null meter.

DC Calibration

NOTE

Zero adjustment must be performed first.

1. Set AC/DC RANGE for 10.
2. Connect calibrating dc source with 8 V to 12 V input.
3. Set *dialamatic* dials for exact value of input voltage.
4. Adjust "L" to null meter (.001% sensitivity).

NOTE

All other dc ranges are ratioed to 10-volt range with temperature-tracking 10:1 dividers. Usually the "L" adjustment will correct long-term reference drifts and will be the only dc adjustment required.

Ratio Adjustment of 1-Volt to 10-Volt DC Range

1. Connect as shown in Figure 3-1 with approximately 10-volt input and switch S1 (Figure 3-1) set to A position.
2. Set AC/DC RANGE for 10 and METER SENSITIVITY for .001%.
3. Measure input voltage with the dials (meter nulled).
4. Now set switch S1 to point B.
5. Set AC/DC RANGE for 1. Meter should remain nulled. If meter is off null, adjust "J" trimmer to null meter.

Ratio Adjustment of 100-Volt to 10-Volt Range

1. Connect as shown in Figure 3-1 with approximately 100 volts input and switch set to B position.
2. Set AC/DC RANGE for 10, and METER SENSITIVITY for .001%.

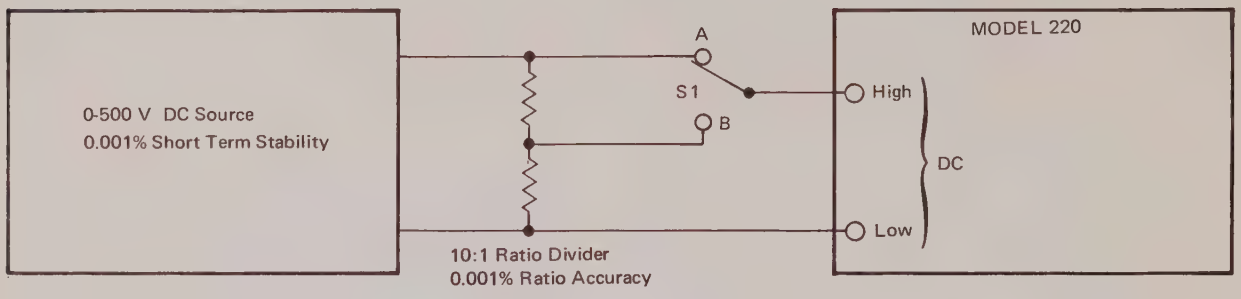


Figure 3-1. Ratio Adjustment of 1, 100, and 1000 Volt DC Ranges to 10 V DC Base Range

3. Set dials to null meter.
4. Now set the AC/DC RANGE switch for 100, and set switch S1 to A position.
5. Meter should null. If meter is off null, adjust "K" trimmer to null meter.

Ratio Adjustment of 1000 VDC to 100 VDC Range

1. Connect as shown in Figure 3-1 with approximately 500-volt input and switch S1 set to B position.
2. Set AC/DC RANGE for 100.
3. Measure input voltage with dials (meter nulled). (METER SENSITIVITY should still be set for .001%.)
4. Now set switch S1 to point A.
5. Set AC/DC RANGE for 1000. Meter should remain nulled. Make a fine adjustment, if required, to exactly null the meter with the "A" trimmer.

NOTE

Model 220 presents a 10-megohm load to the voltage source in the 1000-volt range. If voltage source is not regulated, this loading must be taken into account.

AC Calibration

1. Connect as shown in Figure 3-2 with near full-scale voltage input at 100 Hz.
2. Set Model 220 controls as follows:
   a. FUNCTION for AC.
   b. AC/DC RANGE for 1.
3. Set dials for exact value of input voltage.
4. Adjust control "B" to null meter.
5. Set AC/DC RANGE for 10 and input for near full-scale voltage.

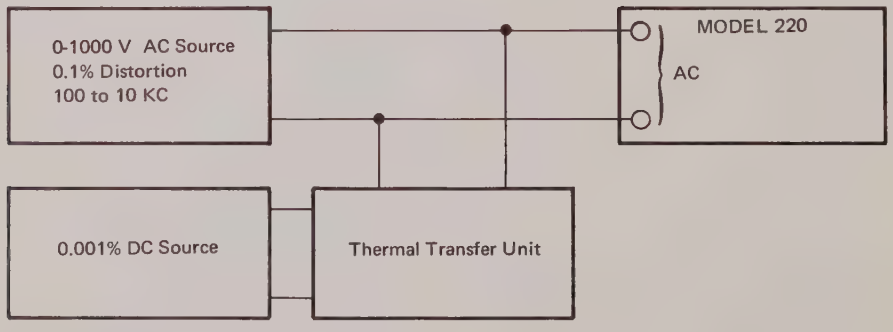


Figure 3-2. Accuracy Adjustment of 1, 10, 100, and 1000 Volt AC Ranges

6. Set dials for exact value of input voltage.
7. Adjust control "E" to null meter.
8. Set AC/DC RANGE for 100 and input for near full-scale voltage.
9. Set dials for exact value of input voltage.
10. Adjust control "G" to null meter.
11. Set AC/DC RANGE for 1000 and input for near full-scale voltage.
12. Set dials for exact value of input voltage.
13. Adjust control "H" to null meter.
14. Change frequency of input voltage to 10 kHz and repeat Steps 2 through 10, except adjust control "C" in Step 4, control "D" in Step 7, and control "F" in Step 10.

Ohms Calibration

NOTE

Ratio calibration, of 1 Vdc range to 10 Vdc range, must be performed before calibration of 1000 ohms range.

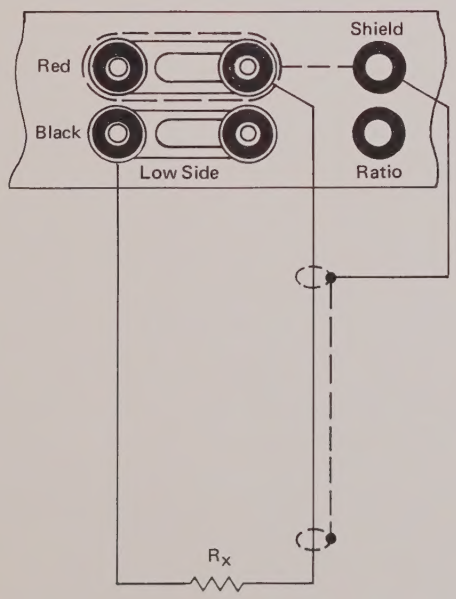
1. Short OHMS INPUT terminals.
2. Set Model 220 controls as follows:
   a. Set FUNCTION for Ω.
   b. Set OHMS/HZ RANGE for 1000.
   c. Set METER SENSITIVITY for .01%.
   d. Set dials for 00000.
3. Null meter with OHMS ZERO ADJUST control on rear panel.
4. Remove short and connect a near full-scale standard resistor (1200Ω top-of-dial range) to the OHMS INPUT terminals.

NOTE

A special SHIELD terminal is provided, primarily for 1-megohm and 10-megohm ranges, to reduce errors caused by ac pick-up and/or dc leakage. *This SHIELD terminal must not be connected to any of the OHMS INPUT terminals or to the OHMS RATIO terminal.* The SHIELD terminal should be connected to the floating shield covering the high ohms input lead. Figure 3-3 shows this connection.

Unless very short leads are used, a 4-wire connection should be made to the OHMS INPUT terminals when using the 1000 ohms range.

Leads should be copper alloy to minimize generation of thermal emf on the 1000 ohms range.



Caution—*Do not* connect shield to measurement or ratio terminals.

Figure 3-3. Shield Correction for High Resistance Measurements (1M and 10M range)

5. Set dials for exact value of standard resistor.
6. Adjust control "N" to null meter.
7. Set OHMS/HZ RANGE for 10 k.
8. Connect a near full-scale standard resistor to the OHMS INPUT terminals.
9. Set dials for exact value of standard resistor.
10. Adjust control "P" to null meter.
11. Set OHMS/HZ RANGE for 100 k.
12. Connect a near full-scale standard resistor to the OHMS INPUT terminals.
13. Set dials for exact value of standard resistor.
14. Adjust control "R" to null meter.
15. Set OHMS/HZ RANGE for 1 M.
16. Connnect a near full-scale standard resistor to the OHMS INPUT terminals.
17. Set dials for exact value of standard resistor.
18. Adjust control "S" to null meter.
19. Set OHMS/HZ RANGE for 10 M.
20. Connect a near full-scale standard resistor to the OHMS INPUT terminals.
21. Set dials for exact value of standard resistor.
22. Adjust control "T" to null meter.

Hertz Calibration

1. Set Model 220 controls as follows:
   a. Set FUNCTION for HZ.
   b. Set OHMS/HZ RANGE for 1 M.
   c. Set METER SENSITIVITY for .001%.
   d. Set dials for 1000.00.
2. Connect 1 MHZ OUTPUT terminal to HZ INPUT terminal.

   NOTE

   Use short cable to prevent capacitively loading 1 MHZ OUTPUT.

3. Adjust control "M" to null meter.

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